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METRIC IMPLEMENTATION IN U. S. CONSTRUCTION

By

ANDREW J. HOLLAND

A REPORT PRESENTED TO THE GRADUATE COMMITTEE
OF THE DEPARTMENT OF CIVIL ENGINEERING IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF ENGINEERING

UNIVERSITY OF FLORIDA

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1. Introduction

1.1. Introduction

Throughout the history of industrialization, people have been trying to develop a single system of measurement with a worldwide acceptance. Since its inception two centuries ago, the metric system has been gaining ground over the traditional "inch-pound" system. Today, the United States remains as the sole user of the "inch-pound" system of measurements.

The pressure for unification into the metric system has been mounting. With the emergence of the "global economy," non-metric products are becoming increasingly unacceptable in the world markets. Individual industries, societies and organizations in the United States have, however, been making steps to adopt metric for some time.

Congress, understanding the need for adoption of the metric system in trade and commerce, has taken steps to introduce metric system into the commercial market of the United States. Federal agencies are now required to use the metric system in governmental related programs including procurements, grants, and other business related activities. However, no nationwide mandate for metric that includes the private sector has been established.

This report contains background information on the development of metric to date, status of metric conversion in the federal government, current metric activities of

professional and industry groups, planning for the metric change by the private sector, technical implications in the construction industries, metric building products and services, as well as a general explanation of the key aspects of metrication for the construction industry in the United States.

1.2. Metric History

Development of the metric system stems from the scientific advancements of the seventeenth and eighteenth centuries. Scientific leaders recognized the need for a method of measurements that was both accurate and international in order to communicate their ideas and discoveries throughout world.

1.2.1. Decimal Measuring System

As early as 1585, the decimal system, as basis of measurement, was proposed by a Flemish mathematician Simon Stevin. In 1670 in France, Gabriel Mouton studied the motion and measurement of the arc of a terrestrial meridian as a base for a natural standard of linear measurement. In 1739, with an idea of a new international standards for division of a terrestrial meridian, Cassini and Lacaille measured the arc of the Dunkirk-Barcelona meridian passing through Paris, France.[1-293]

The French Revolution provided the real push for further development of the decimal system. In their enthusiasm for social and political changes to the European traditions, French sought to reform the existing measurement systems. The new system

was to be designed around the following principles advocated by scientists and mathematicians:[1-298]

- Decimal numbering system should have a decimal measuring system.
- Units of length, volume and weight should have a direct relationship to each other.
- The value of the basic units of measurement should be a unchanging, absolute standard of the physical universe.

1.2.2. Metric System Developed

In 1790, the French National Assembly established a decimal based system of measurement and in 1793, the new unit of linear measurement was named "meter" based on Cassini-Lacaille's measurement of the arc of the Dunkirk-Barcelona meridian (1/10,000,000 of meridian quadrant measurement). Soon after, Lavisier's experiments with one cubic decimeter of distilled water at the freezing point became the basis for the provisional measures for weight named "kilogram."[1-294]

In 1799 the provisional meter and kilogram were replaced by more accurate standards. A platinum meter and kilogram were placed on deposit in the Institute National des Sciences et des Arts to be copied and made for use as the French national standards. However, confusion, abuse, fraud and lack of acceptance by the general public required the French Government to pass a decree in November 1800, which stated that the decimal system of weights and measures would be mandated for the entire republic. [1-294]

1.2.3. Metric System Accepted

In May of 1875, seventeen signatory nations which included the United States participated in the "Treaty of the Meter" in Paris, France. The International Bureau of Weights and Measures (BIPM) was established and has now grown to include 44 countries worldwide. The purpose of the International Bureau of Weights and Measures was to ensure worldwide unification of physical measurements and is responsible to: [1-296]

- Provide standards of measurement for worldwide use.
- Establish the standards and scales for measurement of the physical quantities and maintaining the international model.
- Conduct comparisons of national and international standards.
- Ensure the coordination of corresponding measuring techniques.
- Carry out and coordinating the findings related to the fundamental physical constants.

1.3. Modern Metric (SI)

Today's metric system is different from the one common a generation ago. As with all systems of units, the metric system has been evolving and several modifications were made to match the progress of science and technology. Today all nations, including the United States, have been unified under one "modern" system, *Le Systeme Internationale d'Units* (the International System of Units), or more commonly known as SI. Established in 1960, the abbreviations SI have been adopted by all nations and languages of the world to identify the new metric system of measurement.[1-297]

The advantages of this new system, simplicity and universality, with its close relationship to the original metric system, led to immediate world acceptance. The new

system has attracted favorable responses especially from engineers, scientists and educators throughout the world. All the nations formerly on the British system of "inch-pound" system have already changed.

Perhaps of greatest importance is the need to widely develop an understanding that SI did not just happen. The impact of SI is not on only one part of the world. SI is the most recent major step in a continuing evolutionary process in the world of measurements. SI represents a movement of high potential for developing the first really universal language.

1.3.1. Key Objectives of (SI)

In building construction the principal objectives of SI includes:[1-6]

- Simplicity - Only one unit is used to describe a measured quantity. It is simple because there are no conversions to remember (inches, feet, yard, miles etc.). Built upon seven "Base Units" which may be expanded into sets of "Derived Units." Most common names and symbols of the base units includes:

Quantity or Measurement	SI Unit	Symbol
length	meter	m
mass (weight)	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Note: "Liter" (L) - special volume name equaling cubic decimeter; may only be used for liquids, gases and particulate.

- Coherence - A family of units in a direct one-to-one relationships between base units and derived units without the use of any multipliers. Example of set of SI derived units:

Quantity	Unit Name	Unit Symbol	Terms of SI
velocity	---	---	m/s
acceleration	---	---	m/s^2
force	newton	N	$kg\ m/s^2$
pressure, stress, modulus	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	N m
power	watt	W	J/s

- Uniqueness of Units - No duplication of derived units. Each unit is used in the same form and with the same name and symbol in all branches of technology. For example; all forms of "energy" whether potential, kinetic, mechanical, electrical or thermal will be measured in terms of "joules."

- Versatility - Convenient unit multiples and sub-multiples to cover wide range of sizes. The most commonly used prefixes in construction are kilo (k) and milli (m).

Factor	Prefix	Symbol
$1\ 000\ 000\ 000 = 10^9$	giga	G
$1\ 000\ 000 = 10^6$	mega	M
$1\ 000 = 10^3$	kilo	k
$100 = 10^2$	hecto	h
$10 = 10^1$	deka	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m

- Symbolization - Unmistakable identification of units and of unit multipliers (prefixes) by standard symbols. The SI symbols are to be used in the same form in all languages of the world.

- Decimalization -Simplified computation and recording similar to the decimal monetary system. Utilization of the decimal system (powers of 10), eliminates need for fractions and compound arithmetic.

- Universality - Strong effort has been made toward universal acceptance for titles of the units. Utilizing the names of widely regarded applied scientists (Newton, Pascal, Joule, Watt) need for language translation requirements has been minimized.

- Reproducibility - Description of base units in terms of reproducible physical characteristics. SI units can be reproduced in physical laboratories around the world.

Note: For purpose of clarification, remainder of this report will utilize the term "metric" as the new international unit (SI).

2. Metric System In United States

2.1. Legislative Activities

Most Americans are not aware of the United State Government's involvement with the metric measurement. In fact, the United States' increasing use of metric units has been underway for many years and the pace has just accelerated in the past two decades. Congress has voted on making this country metric several times, starting as long as 200 years ago.

Starting in 1790, the United States was busy working on its Constitution, which included provisions for standard of weights and measures. Secretary of State Thomas Jefferson submitted two plans to the Congress for establishing our own standards of weights and measures. In spite of strong support from the President George Washington, neither plans were adopted. Britain being the main trading partner of United States, a decision was made to retain the British measurement system of "inch-pound".[1-295]

While France and other nations, adopted the metric system, the debate about standards continued in the United States. In 1816, President Madison reminded Congress that "the lack of uniformity in weights and measures was an unfinished business." Following this, in 1821, John Quincy Adams submitted a comprehensive report on the desirability of the metric system, however no action was to follow.[2]

2.1.1. Metric Legalized In U.S.

In 1866, the metric system of measurement was formally recognized and made legal for use in the United States. The Congress defined the "yard" as equal to 3600/3937 of a meter which resulted in the relationship of "1 in = 25.4 mm." Our customary measurements of "inch-pound", have been defined in relation to the meter and kilogram ever since. Congress supplied each state with a set of standard metric weights and measures, however no movement was made to support a national changeover.[3]

2.1.2. Metric Study Of 1968

Congress authorized the Department of Commerce to conduct a three-year study of this Nation's systems of measurement, with particular emphasis on the feasibility of adopting (SI). As part of the study, an advisory panel of 45 representatives consulted with and took testimony from hundreds of consumers, business industries, labor groups, manufacturers, and state and local officials.

The panel's report concluded that measurement in the United States was already based on metric units in many areas and that it was becoming more so every day. The majority of participants in the study believed that conversion to the metric system was in the best interests of the Nation, particularly in view of the increasing importance and influence of technology in American life and our foreign trade.

2.1.3. Metric Conversion Act Of 1975

Among the more recent legislation that caught public attention was the 1975 Metric Conversion Act, signed by President Gerald Ford on December 1975. This Act was enacted in order to set forth the policy of the U.S. to convert to the metric system.[1-299]

It requires that each federal agency use the metric system of measurement in its procurements, grants and other business related activities, unless that use is likely to cause significant cost or loss of markets to United States firm, such as when foreign competitors are producing competing products in non-metric units.

The Act lacked a clearly stated objective and a timetable for implementation and as a result most consumer oriented U.S. companies did not change their products. A voluntary move was perceived by them as an annoyance to their customer, the American public. A few years after the law, it seemed metrication was losing ground rather than gaining. Even the U.S. schools that started teaching metric relaxed it later. The voluntary metric transition process eventually lost momentum.

2.1.4. 1988 Omnibus Trade Act

In mid-1980's, the U.S. recognized the steady increase in foreign imports in relation to our exports. Yielding to the urging of NATO, commercial allies, U.S. citizens and lobbying groups, congress moved to modify the 1975 law to make it "less" voluntary and gave it a deadline. In 1988, President Reagan signed into law the Omnibus Trade and

Competitiveness Act. It amends the Metric Conversion Act of 1975 by the following mandates:[1-300]

- Designate the metric system of measurement as the preferred system for U.S. trade and commerce.
- Requires each federal agency to convert to the metric system by the end of fiscal year 1992.
- Requires each federal agency to establish guidelines to carry out the policy.
- Requires each federal agency to report to Congress on the implementation action taken and planned.
- Requires the comptroller general to review the implementation actions and make recommendations.
- Established an ombudsmen and procedures in order to ensure the effective implementation of the exception while eliminating significant problems in its implementation.

2.1.5. The Executive Order Of 1991

In order to accelerate the metric usage within the Federal Government, President George Bush signed the Executive Order 12770 on July 1991. This Executive Order authorizes:[4]

- The Secretary of Commerce to issue regulations to carry out government metrication and to report annually the progress being made in metric use.

- The Secretary of Commerce to direct and coordinate the federal agency metric transition and to assess progress in annual reports to the President.
    1. The National Institute of Standard and Technology has been tasked to carry out the direction and coordination responsibilities of the Secretary of Commerce.

2. Required all agencies to submit detailed metric transition plans to the Department of Commerce. Agencies were required to develop plans for implementation by 1993 through 1996 fiscal years.

2.1.6. Savings In Construction Act Of 1996

An effective and controlled implementation was needed to avoid impractical or economic inefficiencies. The Savings In Construction Act Of 1996 (formerly known as the "Cox bill") amended the Metric Conversion Act by:[5]

- A Federal Agency may require that specifications for structures or systems of concrete masonry be expressed under the metric system of measurement, but may not require that the concrete masonry units to be "hard-metric" converted products.

- The Federal Agency may not require that lighting fixtures be converted products unless the predominant voluntary industry consensus standards are "hard-metric."

The law only applies to the concrete block and the type of recessed lighting fixtures used in suspended ceilings. It requires each agency to appoint a Construction Metrication Ombudsman to handle metric-related complaints. Thus far, aside from lighting and block producers there has been no complaints. The law applies to federal projects put out for bid after January 1997.

2.2. Conversion Progress In Federal Agencies

Federal construction agencies developed specific timetables and milestones for designing and constructing all new projects in the metric system. Reports show that most federal construction programs are now fully converted with the few remaining agencies to

be converted. Billions of dollars in metric projects are under design and construction. Here is an agency-by-agency update:[6-2]

- General Services Administration (GSA) - GSA is the largest of the federal government's construction agencies. GSA's Public Buildings Service, the "federal landlord," builds for numerous other federal agencies. It has essentially completed the metrication of its new construction program.

- Federal Highway Administration (FHWA) - The FHWA pushed back the 1996 deadline to 2000 as the target date after which no highway projects may be paid for with Federal funds unless the plans, specifications and estimates are all in metric units. Despite this option, 44 states including Florida Department of Transportation decided to stay with the original deadline. Current metric projects total $3 billion and will grow to $20+ billion by 2000.

- Army Corps of Engineers (USACE) - After October 1996, all new Corps military construction projects will be constructed in the metric system. $400 million in metric military projects are under construction or awaiting award and $730 million are in design. Overseas, the Corps is administering over 300 metric projects with a value of $1.8 billion. There have been no discernible cost premiums associated with metric use to date. The Corps' guide specifications have been converted and all standard designs, technical manuals, design guides, and related criteria are being developed, updated, or revised in metric units.

- Naval Facilities Engineering Command (NAVFAC) - After October 1996, all major Navy construction projects will be designed and built in the metric system. Navy has completed the conversion of its guide specifications for stateside metric projects and used the metric system in all overseas projects. At the Navy's request, the Construction Metrication Council placed a Special Notice in the Commerce Business

Daily on announcing the government's transition to the metric system and advising the U.S. construction industry to prepare for the change.

- Air Force (USAF) - Uses the Army Corps of Engineers and the Naval Facilities Engineering Command as its construction agents. It will design and build all new projects in the metric system after October 1996.

- Coast Guard (USCG) - In phases, beginning January 1996, has three metric pilot projects under design and is incorporating metric measures in its standards manual. Approximately $11 million in metric projects are now under construction. All work ($50-100 million annually) will be built in metric after 2000.

- State Department - The Department of State's construction program has virtually always designed and built in the metric system. Projects include embassy office buildings, commissaries, motor pools, Marine Corps guard quarters and related security facilities, and recreational facilities.

- Architect of the Capitol - A new Library of Congress storage facility is being planned for Fort George G. Meade in Maryland. It will be the first building designed in the metric system by the Legislative Branch.

- Veterans Administration (VA). In addition to the $70 million VA data center, the largest metric building constructed in the United States, the VA has initiated four metric pilot projects with a total value of about $50 million. All of the VA's construction standards, design manuals, and guide specifications have been converted to the metric system since June 1995.

- National Aeronautics and Space Administration (NASA) - Each NASA field activity has designed and constructed at least one metric project to date. Since October 1995, all NASA projects are built in metric.

- Federal Bureau of Prisons - Design guidelines for new facilities were converted to metric units in August 1994. Four metric projects totaling $374 million are in the design stage. Began in October 1996, all prison facilities are being designed in the metric system.

- Smithsonian Institution - January 1994 - Virtually all work, including maintenance and repair, has been performed in metric for the past three years. The value of these projects is about $60 million annually. The $30 million National Museum for the American Indian Cultural Resources Center was recently awarded under budget with another $300 million in metric projects in the planning/design stages. Metric conversion in the design phase and construction phase have been very successful.

- Department of Energy (DOE) - January 1994 for major projects - Many DOE labs and sites have ongoing metric construction programs.

- Department of Agriculture (USDA).- Design and construction of all new projects in the metric system began in January 1995. A $40 million office facility in Beltsville, Maryland, is under construction and the modernization of the USDA South Building will be renovated over 10 years for a total cost of approximately $160 million.

- Indian Health Service (IHS). - All projects has been designed and constructed in metric since January 1994. The IHS health care facilities and quarters construction program has been converted completely to the metric system. Training programs are being provided for tribal officials, subcontractors, and construction workers. Currently, the IHS has 95 metric projects in design, 15 under construction, and 21 completed.

- National Institute of Standards and Technology (NIST) - Since January 1994, all capital improvement projects at the Institute's Gaithersburg, Maryland, and Boulder,

Colorado, campuses are being designed and built in the metric system. The $75 million Advanced Technology Laboratory is under construction and will be completed in 1998. Several metric projects are under construction and have encountered minimal problems.

- National Aeronautics and Space Administration (NASA). NASA began design and construction of all new projects in the metric system beginning in FY 1996. Thirty-one pilot projects valued at over $40 million are in design or construction and there have been no major problems to date.

- Tennessee Valley Authority (TVA). Since October 1995, the TVA has used the metric system for all designs, procurements, and construction projects unless they involved modifications to an existing generating plant, navigation lock, or power transmission system. TVA recently began construction of its first metric project at Fort Loudoun Dam.

- National Institutes of Health (NIH). Since January 1994, all new NIH projects have been designed in the metric system. Metric training has been provided to a wide range of facilities personnel and a number of contractor personnel.

- U. S. Postal Service (USPS) - No formal date has been set at this time for the total conversion to the metric system, but several metric pilot projects are under way. The Postal Service has began design on three new facilities in the metric system: a post office in Milwaukee, Wisconsin; a mail processing annex in Twin Falls, Idaho; and a mail processing plant in El Paso, Texas.

- Administrative Office of the U.S. Courts (AOUSC)- The GSA manages construction for the AOUSC and all new federal court facilities have been designed in the metric system since January 1994. Five new courthouses with total value of over $1 billion are currently underway.

- Internal Revenue Service (IRS) - The GSA manages construction for the IRS, and all new IRS projects have been designed in the metric system since January 1994. Four major renovation projects, totaling $100 million was completed in 1996. Smaller projects are designed in-house in metric.

- Naval Sea Systems Command (NAVSEA) - Ships and boats use many of the same construction components as buildings, particularly structural steel and mechanical and electrical equipment. The Navy's newest ships will be required to be designed in metric. It will utilize steel plates rolled to whole millimeter thickness and structural steel specified in accordance with ASTM A6M. U.S. shipbuilders are considering converting their entire operations to the metric system as they position themselves to re-enter the worldwide commercial shipbuilding market.

All sectors of the Federal Government Agencies have made great strides in establishing guidelines, issuing reports and implementing the use of metric in their procurement programs. More and more agencies are moving aggressively as they find that metrication is easily achievable. Although some federal agencies have moved faster than others in converting to the metric system, all federal agencies will be converted to metric by the year 2000.

3. Reasons For Converting To Metric

3.1. Federal Construction Programs

Although not mandatory for the private sector, the use of the metric system in the federal agency programs is intended to support U.S. industry's voluntary adoption of metric use and to help catalyze a broader metric transition that will achieve the full economic benefits of metric use.

Procurement is the primary federal tool and will encourage and help the U.S. industry in converting voluntarily to the metric system. The buying power of the U.S. Government is enormous. The direct financial benefits from selling to the government are expected to have a positive influence on the U.S. industries.

Federal construction represents a big chunk of the nation's $500 billion-a-year construction industry. Federal appropriations for construction total about $50 billion, 10% of the U.S. construction industry.[7] Such a large expenditures will expose a significant portion of the U.S. construction industry to metric. No one in the construction industry will want to work with two different systems of measurement for very long, so chances are that U.S. construction will convert predominantly to metric within the next five to ten years.[8]

3.2. International Demand For Metric

Until recently, most U.S. industries did not see the need for metric usage because use of non-metric units was not a barrier to business transactions, either domestically or internationally. Many of our major trading partners had been using the same system of units as we were using. However since 1975, several changes in international commerce created the economic necessity to use the metric system in U.S. industry:[9]

1. All of our non-metric trading partners, including England, Canada, Australia, and China, completed conversions to use of the metric system.
2. The emergence of the "global economy," where products move easily across national boundaries. These products must be compatible with the design, fabrication, maintenance, repair, and disposal systems that are used for these life cycle processes.
3. Increasing international standards that are consistent, compatible and complementary throughout the world.
4. Shift in power and influence in the world affairs, from military strength to economic strength.

As the international standard of measurement, the metric system is one key to success in the global marketplace. International standards have become an important factor in international economic competition. Non-metric products are becoming increasingly unacceptable in world markets that favor metric products.

Every country which has adopted an improved measuring system during the past century has moved to a metric system. During U.S.-Japanese negotiations to reduce the

trade deficit, the Japanese have identified non-metric U.S. products as a specific barrier to the importation of U.S. goods.

The metric system as an international standard, its use in product design, manufacturing, marketing and labeling is essential for those sectors of the U.S. construction industry that export goods or services. The foreign billings of American architecture, engineering and contracting firms amounted to $3.2 billion in 1989 with about third of this from Europe.

Some sectors of the construction community, such as the wood industry, have shipped exports in metric for many years. In 1990, U.S. non-lumber construction product exports totaled about $2.8 billion and imports totaled about $4.2 billion. Even without the federal impetus, there is a growing consensus that it is in the U.S. construction industry's long-term interest to "go metric."[8]

3.2.1. European Common Market

In 1992, 12 European nations; Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and the United Kingdom merged into one powerful economic marketplace. The European Community, now the world's largest market, with a population of 375 million and gross domestic product of $7,000 billion, has specified that products with non-metric labels will not be permitted for sale after 1992.[10]

As a condition for becoming a member of the European Common Market, Great Britain, long-time trading partner of U.S., also began a transition to the metric system in 1965. The conversion of Great Britain and the Commonwealth Nations to metric created a new sense of urgency regarding the use of metric units in the United States.

European Community could become even more economically influential as the countries of the European Free Trade Association; Austria, Finland, Iceland, Norway, Sweden and Switzerland cooperate closely with the European Community. Now even the newly independent countries of the Eastern Bloc are looking for new forms of East-West European cooperation and are considering affiliation with the European Community.

3.2.2. North American Free Trade Agreement

In forming the North American Free Trade Agreement, United states with its two largest trading partners, Canada and Mexico, merged into a powerful economic marketplace with population of 360 million and a total economic annual output of $6,000 billion. It will create the second largest free trade zone in the world, after the European Community.[10]

Canada and Mexico are predominantly metric countries. Canada has committed itself to the metric system since the late 1970's, but the conversion of certain sectors depends upon U.S. progress toward adopting the metric system. Canadian lumber industry ships 75% of its product to the United States (25% of U.S. consumption), so that

details of the metric changeover for this industry must necessarily be coordinated with the decisions and timing of the U.S. construction industry.

3.3. Minimal Change Required

The British, Australians, South Africans and Canadians all converted from the inch-pound system to metric during the past 20 years and encountered only minimal problems in converting the construction industry. In fact, the conversion proved much less difficult than anticipated since much work is built in place and most manufactured components can be used without dimensional change.[8]

The architecture/engineering community preferred metric dimensioning since it was less prone to error and easier to use than feet and inches. Design firms found that it took a week or less for staff to begin thinking and producing in metric; most trades people adapted in only a few hours. Engineering calculations were faster and more accurate because there were no unit conversions and no fractions.

Metric offered a one-time chance to reduce the many product sizes and shapes that had accumulated over the years but were no longer useful, thus saving production, inventory, and procurement costs.

3.4. Minimal Cost Increase

Initial thought of most experts on the cost of converting the construction industry to the metric system would be substantial, however, the actual cost of metric conversion

has been far lower than expected. Although it seems logical that there must be some cost associated with metrication, major contracts awarded to date have not shown any noticeable change in the cost of construction.[8]

Billions in federal construction projects have been completed and thus far, the costs are consistently in line with conventional construction. There was no appreciable increase in either design or construction costs, and conversion costs for most construction industry sectors were minimal or offset by later savings. There are so many variables which may affect construction costs that changing the measurement system appears to be relatively insignificant.[11]

As the conversion progresses, any cost associated with conversion to metric will be recovered in form of reduced man-hours in education and calculation and in reduction of errors due to the simplicity of the metric system. Even more important, by providing an opportunity to rationalize sizes and specifications of building products, we will not only recover the initial costs of the changeover, but reduce overall costs.

3.5. Developing Technology

American design and construction firms has been using metric system in foreign work for number of years with no reported problems. The use of computer-aided design and drafting systems continues to increase, and most engineering and cost calculations are performed on computers.

Virtually all HVAC system controls are digitized and computer-controlled manufacturing operations are now common. In each of these areas, computers make switching between the "inch-pound" system and the metric system simple.[8]

In recent years, global communications, by way of computer through the use of the "Inter-Net," have been developed to link the whole world. Advancements in this technology has grown with such intensity that, from a business point of view, the use of international measuring units is not only advisable but, absolutely necessary.

3.6. Metric Advantages

A simple and rational measurement such as the metric system will provide the greatest long-range serviceability to the professions and to the public at large.

In summary, the primary reason for converting to the use of the metric system is the need to maintain and improve our efficiency of operation on an international basis and thus stay competitive. Simplified reasons for changing, includes:

- An opportunity to rethink many industry standards and to take advantage of size standardization. Also, when the remaining construction industry adopts the metric system, they will come into conformance with federal agencies engaged in similar activities.

- Metric offers a one-time chance to reduce the many product sizes and shapes that had accumulated over the years but were no longer useful, thus saving production, inventory and procurement costs.

- By adopting the metric system, which is the international standard of measurement, we can improve our competitiveness and our ability to sell our products in world markets. This will increase our exports and improve our balance of trade.

- Metrication will increase the construction industry's efficiency, production rate and quality control, thereby making it more cost-effective at home and better for competition abroad.

- Metrication has a one-time cost while its benefits are endless.

4. Impact On U.S. Construction Industry

4.1. U.S. Metric Policy

The Congress perceived that it was in our self interest to change to the use of the metric system in trade and commerce, reflecting a long-term, visionary thinking. The benefits included not only the advantages to be gained by metric usage, but also the costs that are being incurred by delaying metric usage, such as diminishing shares of world markets and a trade imbalance that is eroding our standard of living.

Federal agencies involved in construction have agreed to institute the use of metric in the design of all federal construction by 1994, 1996 and 2000. The intent of the law was to make the United States more competitive in international trade by bringing its measurement system into line with that of the rest of the world, which now is virtually all metric.

Although federal agency use of the metric system is mandatory, metric use is voluntary for industry. So even while the benefits will be gained by the industry, conversion is still the industry's choice and the federal government is not forcing universal use of metric units or the changing of products to meet metric standards.

In 1975, when the Metric Conversion Act was passed, the entire metric transition process initiated was completely voluntary and broadly based. The process was not embraced by the industry or government. For most industry sectors, there was no

apparent urgent economic necessity of the change to metric. In the general population, the process not only failed to be embraced, but instead raised anxiety and was actively resisted.

As construction metrication efforts continue, the Government's construction agencies are committed to work closely with all interested private sector parties: building material manufacturers, trade associations, design firms, and construction contractors. Consensus, efficiency, and cost-effectiveness will be the goal.[4]

The Federal agencies will conduct market research to determine the availability of modular metric construction products prior to developing new procurement specifications. Procurement officials in each agency, to the maximum extent practicable, will specify commercial items or non-developmental items other than commercial items to meet the needs of the agency.

Throughout the acquisition process, the Federal agencies will ensure that they give due consideration to the known effects of their actions on State and local governments and the private sector, paying particular attention to effects and possible cost burdens on small business.

4.2. Impact On Construction Trades

Construction industry accounts for 6 million jobs and 8 percent of the gross national product.[12] Compared with the rest of the U.S. industry, the construction industry

has few compelling reasons for the changeover; we export little. But other U.S. industries such as nation's automobile, medical, health care, pharmaceutical, machine tool, heavy equipment and electronics industries, among others, are converting to metric and it will be difficult for the construction industry to remain on the traditional measurement system once the general population becomes educated to think in metric terms.[13]

It should be no surprise that the construction trades are proving to be the most adaptable sector of the construction industry in converting to the metric system. People in the construction trades tend to be technically oriented and many already use metric tools to maintain their vehicles and equipment. Work is still performed in the same way by the same people with the same skills, the same experience, with only a minor changes in the tools and equipment. On a metric construction job, they are fully immersed in the use of metric measures, which may be the best and the fastest way to learn.

Those who have already experienced the metric conversion believe that it was much easier than expected. There will be some minor adjustments and we shouldn't ignore them, but construction is a problem-solving process. On a scale of difficulty from "one to ten" with "ten" being the hardest, metric conversion is said to be about "two."

Plumbing and HVAC personnel must learn the additional metric measures for mass, volume, pressure, force and temperature; however, most seem to welcome the change to a simpler, decimal-based system. Electricians, of course, have always worked in the metric world of volts, amps, and watts.

4.3. Impact On Engineering

American architectural, engineering, and construction firms has been routinely using metric measures in their foreign work for decades. In this country, government building and highway projects are beginning to expose a significant part of the industry to the metric system.

The architecture/engineering community prefers metric dimensioning since it is less prone to error and easier to use than feet and inches. Engineering calculations are faster and more accurate because there is no unit conversion and no fractions. There is no appreciable increase in either design or construction costs, and conversion costs for most construction industry sectors is minimal or offset by later savings. Design firms now find that it takes a week or less for staff to begin thinking and producing in metric.

1. As a new language, metric provides a much-improved, universal, precise, and simplified technical language for the description of engineering quantities. The metric system enters into all aspects of engineering measurements, computations, specifications and graphics.

2. As a new standard, the metric system is having an important impact on the engineering standards which define policy, rules, techniques, sizes, shapes, modules, etc. There is a new set of international standards emerging which is described or will be described in terms of metric units.

The National Council of Architectural Registration Boards (NCARB) has been automated into using computers for their testing of the Architect Licensing Examination

since February of 1997, and has announced that it will fully implement the metric system of measurement in its testing and phase out "inch-pound" units by 2004.[14]

The easiest way to learn metric would be to simply move from the traditional world of measurement to the metric world, forgetting everything we ever knew about inches, pounds, etc. But, for a while, our drawings and our thinking are going to have to be done in "dual dimensioning" using metric conversion factors for conversion from "inch-pound" to metric units. Listing of common metric conversion factors is provided in the Appendix A.[15] Construction plans will show both traditional and metric dimensions and then gradually, the traditional measurements will be phased out.

Appreciable saving of time can result for both the draftsman and the user when metric drawings can be marked: "dimensions in millimeters (mm)" or "dimensions in meters (m)." Dual dimensioning on a drawing itself should be avoided. If necessary, add a table of equivalent dimensions on the same sheet. Placing both "inch-pound" and metric units on drawings increases dimensioning time, doubles the chance for errors, makes drawings more confusing, and delays the learning process.

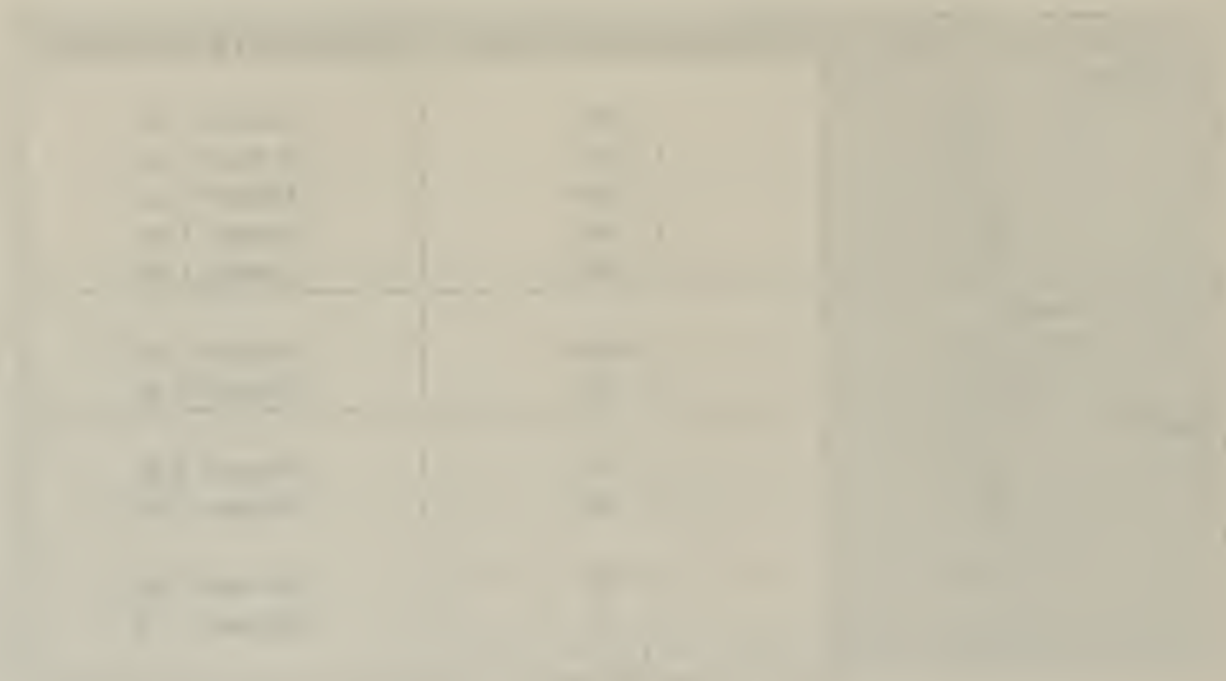
Commonly used drafting scales will change somewhat but all scales will be on the same decimal basis. It also eliminates the difference in the concept between architect and engineer scales. Comparisons between customary and metric scales are shown below:

Customary Scale	Comparable ISO Scale	Metric (SI) Relationship
Site Plans		
1/16" = 1'0"	1 : 200	5 mm = 1 m
1/8" = 1'0"	1 : 100	10 mm = 1 m
1" = 20'	1 : 200	5 mm = 1 m
1" = 50'	1 : 500	2 mm = 1 m
1" = 100'	1 : 1000	1 mm = 1 m
Building Designs		
1/8" = 1'0"	1 : 1000	10 mm = 1 m
¼" = 1'0"	1 : 50	20 mm = 1 m
Details		
½" = 1'0"	1 : 20	50 mm = 1 m
¾" = 1'0"	1 : 10	100 mm = 1 m
1" = 1'0"		
1-½" = 1'0"	1 : 10	100 mm = 1 m
3" = 1'0"	1 : 5	200 mm = 1 m
1" = 1'0"	1 : 1	

4.3.1. Changed vs. Unchanged

The metric modules and grids will be based on rounded, easy-to-use dimensions; basic building module from 4 inches to 100 mm and the planning grid from 2' x 2' to 600 x 600 mm, which is the international standard.[16]

- Drawings - Units, from feet and inches to millimeters for all building dimensions and to meters for site plans and civil engineering drawings will be changed. Drawing contents will however remain the same. Use of dual units (both inch-pound and metric) on drawings will increases time, errors, confusion and only postpones the learning process. In accordance with ASTM E621, centimeters will not be used in construction because:
    1. They are not consistent with the preferred use of multiples of 1000.
    2. The order of magnitude between a millimeter and centimeter is only 10 and the use of both units would lead to confusion and require the use of unit designations.



3. The millimeter is small enough to eliminate decimal fractions.

- Specifications - Units of measure will be changed;
    1. feet and inches to millimeters for linear dimensions.
    2. square feet to square meters for area.
    3. cubic yards to cubic meters for volume (except use liters for fluid volumes).
    4. other "inch-pound" measures to metric measures as appropriate.

Everything else in the specifications will remain the same. Use of dual units in specifications is not recommended except when an "inch-pound" unit serves to clarify an otherwise unfamiliar metric unit. All unit conversions should be checked by a professional for allowable tolerances.

- Floor Loads - Load designations will change, from "psf" to "kg/m^2" for everyday use and "kN/m^2" for structural calculations. Load requirements will remain the unchanged. "kg/m^2" will be used to designate floor loads because live and dead loads (furniture, filing cabinets, construction materials, etc.) are measured in kilograms. However, "kN/m^2" is the proper measure for used in structural calculations.

4.4. Impact On Construction Products

Non-use of metric system by the United States creates unnecessary barriers and by eliminating this restriction, we avoid restricting our products and services to within our own boundaries while the rest of the world goes about its business. Some American manufacturers, such as Otis Elevator, has already switched to metric to increase their international competitiveness and to reduce their parts inventories.[8] Other sectors of the construction community, such as the wood industry, have shipped exports in metric for many years.

4.4.1. Hard vs. Soft Metric

There are two approaches to the metrication of building products and specifications. A "soft-metric" conversion means that the physical dimensions of the product remain unchanged while the measurement units used to describe and specify the product are changed to metric units. A "hard-metric" conversion means physical dimensional change into the internationally recognized building module of 100 millimeters.[17-17]

Although the construction industry is primarily a domestic industry, the need to convert to metric still exists. A handful of products which are considered to be modular products, such as suspended ceiling grids, drywall, plywood and rigid insulation, raised access flooring, brick, and concrete block fall in the category of "hard-metric" and therefore will need their dimensions changed to the new rounded metric numbers.

Everything else (approximately 95% of the construction products) will be simply re-labeled in "soft-metric" since they are not modular or panelized products. Some basic construction materials such as brick, block, and concrete are made and used locally, however, a large number are or can be exported (e.g., glass, coatings, finishes, fasteners, structural steel, wood and wood composites and most electrical, HVAC, mechanical, plumbing and conveying equipment). Each product manufacturer must decide if and when to change its products to rounded or "hard metric" numbers.

4.4.2. Federal Guidance On Modular Products

The Federal Agencies involved in the construction of federal buildings and facilities have worked closely with the private sector to reach common consent concerning modular building products among the interested parties: building product manufacturers, trade associations, design firms and construction contractors.

The statutory language used in the legislation provides the flexibility for appropriate implementation of the metric policy on modular construction products;

> "*The Federal agencies are required to forego metric conversion when it is impractical or is likely to cause significant inefficiencies or loss of markets to United States firms.*"[4]

The intent of the law is to implement metric for increased cost-effectiveness, productivity in U.S. business and greater access to international markets while avoiding any undue burden on the U.S. construction industry.

On federal building projects, metric block may be specified if its total installed cost is estimated to be equal or less than for "inch-pound" block. The federal construction agencies are aware of the cost to the concrete masonry industry of buying the molds needed to produce concrete block in hard metric sizes and are attempting to minimize this expense. In government construction projects, concrete block in a "hard-metric" sizes will only be specified in cases in which the block will be located in an architecturally exposed area or will be required to fit together with other modular metric components.

Further guidance on the federal acquisition of modular metric construction products is available from the Construction Metrication Council of the National Institute of Building Sciences. Guidance is also available from the General Services Administration and its Metric Design Guide.

4.4.3. Changed vs. Unchanged

Modular construction products: brick, block, drywall, plywood, suspended ceiling systems, and raised floor systems, will undergo the "hard" conversion.[16]

- Brick - Standard brick dimensions will be changed to 90 x 57 x 190 mm with mortar joints changed from 3/8" and 1/2" to 10 mm. Many common brick sizes are within a millimeter or two of metric modular sizes and nearly all can fit within the 100 mm module vertically by slightly varying mortar joint widths.

- Concrete Block - Concrete block is considered a modular product. Basic block dimensions will need to be changed to 190 x 190 x 390 mm and mortar joints from 1/2" to 10 mm.

- Drywall & Other Sheet Products - Widths will be changed, from 4'-0" to 1200 mm and heights, from 8'-0" to 2400 mm, 10'-0" to 3000 mm. However, thickness will remain unchanged, so fire, acoustic, and thermal ratings won't have to be recalculated. Metric drywall and plywood are readily available but may require longer lead times for ordering and may cost more in small amounts until their use becomes more common.

- Wallboard - A variety of manufacturers make wallboard to fit the 100 mm module, but there may be a cost premium for small orders and longer delivery times for all orders since metric wallboard is not yet a stock product. While the use of metric wallboard is

desirable in metric construction projects, its use is not mandatory on small projects if project length or cost will increase. The Federal Agencies will only specify wallboard sheet type and thickness without specifying length and width, where framing spacing is specified to fit modular metric construction.

- Plywood & Particleboard - Wood-based sheet products can be produced in a 1200 mm width and 2400 and 3000 mm lengths. There may be a premium for small orders and longer delivery times for all orders since metric plywood and boards are not yet stock products. The Federal Agencies will only specify wallboard sheet type and thickness without specifying length and width, where framing spacing is specified to fit modular metric construction.

- Raised Access Flooring - Grids and lay-in floor tile will be changed, from 2' x 2' to 600 x 600 mm. However, grid profiles, tile thickness, and means of support will remain the same. A number of manufacturers make raised access flooring to fit the 100 mm module, but there may be a cost premium for small orders and longer delivery times for all orders. The Federal agencies will specify metric raised access flooring if costs are generally comparable to inch-pound access flooring and procurement lead times are acceptable.

- Ceiling Systems - Grids and lay-in ceiling tile, air diffusers and recessed lighting fixtures will be changed, from 2' x 2' to 600 x 600 mm and from 2' x 4' to 600 x 1200 mm. Grid profiles, tile thickness, air diffuser capacities, florescent tubes and means of suspension will remain same as before. On federal building projects, metric recessed lighting fixtures may only be specified if their total installed costs are estimated to be equal or less than the "inch-pound" fixtures. All components, T-bars, hangers, ceiling tile, recessed lighting fixtures and recessed air diffusers are available in modular metric sizes from a variety of manufacturers.

- Rigid Insulation - Currently available only in inch-pound sizes and must be cut to fit 400 or 600 mm framing spacing. The Federal Agencies will only specify sheet type and thickness without specifying length and width, where framing spacing is specified to fit modular metric construction.

- Batt Insulation - Nominal width labels will be changed from 16" to 400 mm and 24" to 600 mm. The width will not change; they'll just have a tighter "friction fit" when installed between metric-spaced framing members.

Custom-fabricated products: cabinets, stairs, handrails, ductwork, commercial doors and windows, structural steel systems, and concrete work, can be made in any size, inch-pound or metric.[16]

- Doors - For most commercial work, doors and door frames can be ordered in any size since they normally are custom-fabricated. Height and width will required to be fabricated while thickness of materials and hardware will remain unchanged.

Dimensions	"Inch-Pound"	Metric
Height	6'-8"	2050 mm or 2100 mm
	7'-0"	to 2100 mm,
Width	2'-6"	750 mm
	2'-8"	800 mm
	2'-10'	850 mm
	3'-0"	900 mm or 950 mm
	3'-4"	1000 mm

All other products: framing lumber, woodwork, siding, wiring, piping, roofing, fasteners, hardware, electrical components, plumbing fixtures and HVAC equipment, will just be "soft" converted. Manufacturers will eventually convert the physical dimensions of

many of these products to "hard" metric sizes, but only when it becomes convenient for them to do so.[16]

- Wood And Metal Framing - Wood product such as 2 x 4 studs is a nominal name and not the finished size so neither wood studs nor other framing lumber will need to change in cross-section. Spacing will be simply spaced at nominal metric length; from 16" to 400 mm and 24" to 600 mm. Everything else will pretty much stay unchanged. "2-bys" are already produced in "soft" fractional inch dimensions so there is no need to convert them to new rounded "hard" metric dimensions. 2 x 4s will eventually be renamed 50 x 100 (mm).

- HVAC Controls - Measurement in temperature units will be changed from Fahrenheit to Celsius. Controls are already in digital so temperature conversions can be made with little modification.

- Sheet Metal - Designation will be changed from "gage" to millimeters. The thickness, which will be "soft-metric" and re-labeled to tenths of a millimeter.

- Concrete - Strength designations will change, from "psi" to rounded to the nearest 5 megapascals (MPa). Everything else will remain the same.

- Steel Reinforcing - Not considered to be a modular construction product because it is buried in concrete and is not required to coordinate dimensionally into the building module. Rebar will not change in size but simply re-labeled in metric.

- Glass - Cut sheet dimensions will be changed from feet and inches to millimeters. However, sheet thickness will not need to changed since sheet glass can be rolled to any dimension and already produced in millimeters.

- Pipe And Fittings - Nominal pipe and fitting designations will change from inches to millimeters. Pipes and fittings are produced in "soft" decimal inch dimensions but are identified in nominal inch sizes for convenience. Therefore, there is no need to "hard" convert pipes and fittings to rounded metric dimensions. Instead, they will simply be re-labeled in metric.

- Electrical Components - The same measurement units that are used today will continue to be used; e.g., volts, amps and watts.
    1. Conduit - Neither metallic nor nonmetallic conduit will change size but they will be re-labeled in metric units. Electrical conduit is similar to piping - it is produced in "soft" decimal inch dimensions but is identified in nominal inch sizes.
    2. Wire - No changes will be required at this time, however, existing American Wire Gage (AWG) sizes will be renamed to metric.

- Structural Steel - Section designations will be re-labeled to metric designations and rounded to the nearest 10 mm; 10-inch to 250-mm and 24-inch to 610-mm section. Like pipe and conduit, steel cross sections are produced in "soft" decimal inch dimensions, but are named in rounded inch dimensions, so there is no need to "hard" convert them to metric units.

4.5. Difficulties & Oppositions

The use of the metric system should not be thought of as a problem, but as a solution. On most construction jobs, metric-related problems have been few to nonexistent and neither cost nor schedules have been effected. Vast majority of the U.S. construction industry seems to be onboard with the metric conversion process, however, there are those who oppose this change and have voiced their concerns:

- Suppliers:
    1. Concrete block and recessed lighting fixture manufacturers have claimed undue hardship on their industry.
    2. Large lighting manufacturers with highly automated production processes oppose metrication and charge higher premium for metric products.
    3. Small suppliers can not afford the retooling, capitalization costs and other expensive production changes required in order to physically change the size of their products.

- Contractors:
    1. Number of metric construction products may cost more for the contractors due to a relatively low level of competition or production capacity
    2. Local contractors, limited to bidding on jobs in their area, are unwilling to change in order to obtain government contracts.
    3. Contractors bidding on small metric projects face difficulty obtaining competitive prices for the metric product.

- Government:
    1. Without coordination, "Hard-metric" requirements have been imposed by some federal agencies without appropriate regard to whether that method is impractical or likely to cause significant costs including a loss of markets to U.S. firms.
    2. A major concern that the preference for metric products may conflict with other federal procurement policies such as full and open competition, the Buy American Act, which initiates preferences for commercial products, energy conservation, and the environmental soundness.
    3. Limited number of bidders. Local contractors, bidding on bulk of government's smaller projects, are unwilling to change in order to obtain government contracts.

5. Metric In Construction Industry

5.1. Metric Management In The Private Sector

The management objective, when dealing with metric system, should be to entirely think, talk, write, compute, draw, measure and record data in metric terms. The use of metric should be applied to the fullest extent whenever and wherever possible.[18]

5.1.1. Guidance For Project Managers

- Convert larger projects first. Buying power is greater, bidders are likely to be more sophisticated, bigger budgets can absorb any learning costs more easily, and everyone has more time to learn metric measures.

- Also consider location. Experience has shown that contractors in urban areas are more likely to submit competitive bids on metric jobs than those in rural areas. If you have a small project in a remote area, it may be better to keep it off the metric list for the time being.

- Hire designers with a positive attitude toward metrication. Metric experience helps, but a "can-do" attitude is more important.

- Although many design jobs are being awarded without a fee increase, small increases sometimes may be justified. Consider each case individually.

- Use metric measures from the start of the project. Never use dual units. If an inch-pound project is past the 30 percent stage, don't switch to metric units without the agreement of the project designers.

- Do not increase cost allowances for construction. While metrication may add a small amount to project costs (some estimate 1 percent), the difference should be within the cost estimate's margin of error. So far, most federal projects have shown no significant cost increases due to metrication nor have schedules or quality suffered. The bidding climate remains by far the most important variable in determining construction costs.

- Some federal agencies require structural and mechanical calculations to be performed completely in metric units; others require only converted results. Metric-only calculations are preferable.

- Ensure that a list of "hard metric" products (those that change to standardized metric sizes) is featured prominently in the contract documents. This prevents problems later by ensuring that bidders are aware of such products "up front" and can price them accordingly.

- In the pre-bid and pre-construction conferences, discuss the differences and similarities between metric and inch-pound projects. Review metric submittal requirements and discuss how and where "hard metric" products, if any, are to be used.

- Make clear in the bid documents and during the pre-bid and pre-construction conferences that all contractor and subcontractor submittals, including catalog cuts and shop drawings, must be provided in metric units. There will be natural resistance to this, particularly from the smaller subs, but it can be countered effectively by making submittal requirements clear at the beginning and firmly holding to them as the submittals begin to come in. Experience has shown that after one or two rejections, the word gets around and there are no further problems. An exception to the submittal rule is whole catalogs; only relevant pages need be copied and marked up.

- Perform design reviews promptly. Some design firms have reported delays in governmental reviews of metric projects.

5.1.2. Guidance For Designers

- Go after metric jobs. Designing in metric units is not difficult, but converting standard details and preparing metric specifications will take extra time and effort for the first few projects. Federal agencies are urged to base their architect/engineer selection criteria more on a "can-do" attitude than on actual metric experience.

- Use your best and most adaptable people. Having a project manager or strong team member with metric experience is a bonus. Younger professionals are often the most eager to take up the challenge.

- Big jobs usually are easier than small ones because a lower percentage of time is spent on the metric learning curve.

- Cost estimation for metric projects has not been a problem.

- The latest model building codes and most standards include metric units.

- Collect appropriate metric publications and tools. Buy metric scales for the staff as a positive gesture.

- When purchasing new CADD and engineering computer software programs, ensure that they include a metric option. Metric-only programs (those that perform their base computations in the metric system) are more likely to prevent input errors. In addition, these programs will process calculations using exact metric values and always provide results in the proper metric units.

- Design in rounded metric sizes on metric projects just as you design in rounded inch-pound sizes on inch-pound projects. Learn to think in metric measures. Most people can do this after working on a metric project for several days.

- Do not design in "inch-pounds" and then convert. Converted numbers make it hard on everyone, especially field personnel.

- When detailing, use good judgment as you convert material dimensions. Round to the appropriate level of accuracy, keeping in mind that metric tape measures are marked in 1 mm, 5 mm, and 10 mm increments. A good policy is to round dimensions to at least 10 mm (2/5 inch) whenever possible. Rarely, if ever, should a drawing denote a dimension less than 1 mm (1/25 inch).

- Always use the proper scales. For instance, the metric scale 100:1 is close to 1/8" = 1'-0" (1:96), but don't be tempted to substitute one for the other.

- Add metric units to the in-house specifications and standard details as you update them regardless of your current involvement in metric work. A separate set of metric specifications is preferable to the use of dual units. Use the correct metric units and be consistent in their application. Do not use clerical staff to convert measurements; professional judgment is required.

- Use care in selecting "hard metric" products. Generally, only modular products (brick and block; drywall, plywood, and other sheet goods; suspended ceiling and raised flooring components, and fasteners) fall into the "hard metric" category. Most other products stay the same size and are simply re-labeled ("soft converted") or are fabricated or molded to any size, inch-pound or metric (for example, ductwork, custom millwork, commercial doors and windows, and pre-cast concrete).

- The key to properly specifying "hard metric" products is to thoroughly research products, suppliers, and costs:
    1. Brick is readily available in metric sizes from most suppliers. Block is available in some areas in metric sizes. Check suppliers and be aware that the metric transition is costly for the block industry and many producers may have difficulty bidding on metric block orders. Where block is used as a backup or in-fill material or where architectural considerations otherwise permit, allow "inch-pound" substitutions or specify only nominal wall thickness and let the contractor choose between inch-pound and metric block.
    2. Drywall, plywood, and most other sheet goods can be ordered in metric sizes but there will likely be a cost premium for small orders. Check with suppliers, especially on small jobs and allow for "inch-pound" substitutions or simply do not specify overall sheet sizes.
    3. All suspended ceiling and raised flooring components are available in metric sizes. On the other hand, recessed metric lighting fixtures with straight fluorescent tubes cannot be placed end-to-end in suspended ceilings; surface mount end-to-end lights.
    4. Only a few kinds of fasteners are available in metric sizes. Check with suppliers. Designate inch-pound fasteners in inch-pound units and metric fasteners in metric units. Obviously, the components of many pre-engineered buildings must be "soft converted," although overall building dimensions and interior partitions usually can be designed to any size.
    5. The metrication of concrete reinforcing steel is unsettled at this time. Specify rebar from either ASTM A615 (the inch-pound standard) or A615M (the metric standard) and allow substitutions.

- Be aware that the Buy American Act has been expanded to include Mexican, Canadian and some European products. This may increase the range of "hard metric" products that can be specified. (Federally funded highway projects are also bound by "Buy America" provisions that do not allow the purchase of foreign products.)

- Work with the project's users to help them understand metric drawings. Experience has shown that this approach is more productive than converting drawings back to inch-pound units. Dual units may be used on drawings shown to the general public.

- There may be delays in reviews by utility companies and state and local governments. Anticipate this and work closely with those involved.

5.1.3. Guidance For Contractors

- Go after metric jobs. Metric construction is not difficult. The everyday construction methods, skills, tools, and processes remain the same; it is mainly the measuring tape that changes.

- Be careful with length and area conversions when preparing your bid. Double check the availability and cost of "hard metric" products.

- Pick your best foreman for the first metric job. Having a foreman or a strong team member with metric experience is a bonus.

- Big jobs usually are easier than small ones because a lower percentage of time is spent on the metric learning curve.

- Avoid lost time and frustration by distributing dual-unit measuring tapes to every person on the job. So equipped, field personnel readily adapt to metric measurements; unequipped, they cannot do their jobs. A small investment in measuring tapes will pay for itself many times over. Be sure to purchase dual-unit type tapes; these serve both as a measuring device and a learning tool because inch-pound and metric values can be compared with every measurement made.

- Talk "metric-only" on the work site and set a "pro-metric tone." Experience has shown that a positive, professional attitude about metrication minimizes problems. Subcontractors may resist metrication at first, but they will come to prefer its simplicity.

- Do not reverse converted metric drawings to "inch-pound" units. Invariably, this leads to costly mistakes on the job site. Resist the temptation! Execute all work in metric units with metric tape measures.

- Be prepared to submit all shop drawings and product literature in metric units and to demand the same from your subcontractors.

5.1.4. Guidance For Tradesmen

Incorporate metric measures in all training programs with the goal of preparing personnel to work comfortably in both inch-pound and metric units. Complete listing of metric units that will be used by the construction trades has been provided by the National Institute of Building Sciences.[19] (Appendix B)

- Train on the job site as needed. Tradesmen working primarily with linear dimensions often require only dual-unit tape measures. Plumbing and HVAC personnel, however, must also be familiar with the metric measures for mass, volume, pressure, force, and temperature. Electricians already work in metric units. Some training tips include:
    1. Determine what metric units each trade needs to use. Train with the goal of "enabling people to perform their jobs with the same or greater degree of efficiency using metric units."
    2. Train at the right time. Training should take place just prior to when metric measures are first used on the job; earlier training is usually ineffective.

3. Train only as necessary to meet the goal of enabling employees to perform their jobs with the same or greater degree of efficiency using metric. In fact, training often can be performed completely on-the-job.
4. Train people to "think" metric." Link metric measurements to familiar objects. Use tools that show only metric units.
5. Teach in a way that allows people to develop the same "feel" for metric units that they have for the units they use now.
6. Recent metric projects have shown that trades people learn to think in metric measures in two to four weeks on the job and prefer working in the metric system thereafter.

5.1.5. Guidance For Product Manufacturers

- When updating product literature, specifications, catalogs or advertising, add metric units as appropriate.

- Add metric units to product labels, markings, and packaging.

- Add metric units to dials and linear scales on tools and equipment.

- Consider changing existing product lines to rounded, "hard metric" dimensions, particularly those for which international standards and markets exist.

5.2. Codes & Standards

Outside the general public, a great deal of work has been done by the global and export oriented companies as well as the officials for the nation's codes and standards. The codes of this country's three model code organizations, BOCA, ICBO and SBCCI have already made changes to their standards:[17-23]

1. Building Officials and Code Administrators International (BOCA) - Chicago; The BOCA National Codes have included metric units since 1975
2. International Conference of Building Officials (ICBO) - Los Angeles; ICBO added metric units to its Uniform Codes in 1994.
3. Southern Building Codes Congress International (SBCCI) - Birmingham; SBCCI added metric units to its Standard Building Code in 1991 and added metric to the balance of its codes in 1994.

The principal working reference document is the American National Standard Metric Practice, ANSI Z 210.1-1976. The standards of NFPA and ASTM now features dual units, "inch-pound" and metric. Many other organizations have added metric measurements to their standards or are in the process of doing so. A complete listing of professional and trade organizations in their metric conversion progress to date has been provided by the National Institute of Building Sciences.[20] (Appendix C)

6. Metric Implementation

6.1. Metric Training

Increasing numbers of trade and professional school graduates are versed in metric usage, as are many young people entering the construction field directly from high school. To them, the preference of the metric system, with its simple base units, coherency and use of decimal arithmetic, is self-evident.

Little classroom training is needed for most crafts. It can usually be performed as "on-the-job" training. Even those reluctant to change will grow to prefer the simplicity and convenience of using decimal-based measurements over the traditional "inch-pound" system. Many trades people use only linear measures, feet, inches and inch-fractions to millimeters, therefore, the change is an easy and positive. A metric tape measure is usually the only new tool they require, and classroom work is rarely needed.

How should design and construction firms, product manufacturers, code officials, and others in the construction industry prepare for metric? The American National Metric Council and the U.S. Metric Association recommend the following management and training measures, which apply to organizations large and small:[21]

1. Top level management must provide a firm commitment to metric.
2. Announcing a formal metric policy, forming a metric committee, and appointing a metric coordinator to chair the committee and act as the organization's metric Representative.
3. Set milestones. Establish a realistic, organization-wide metrication schedule with milestones and a completion date.

4. Collect information. Begin a metric reference library.
5. Develop training objectives. Write carefully worded, measurable training objectives with the goal of "enabling employees to perform their jobs with the same or greater degree of efficiency using metric."
6. Define the learner population. Determine who needs to know metric and to what extent they need to know it. Some employees may require an in-depth working knowledge of metric whereas others may never need to know it at all. Most probably will need to know only a few metric units.
7. Determine training needs. There are three kinds or levels of training: metric awareness training to help all employees overcome fear and resistance to change, management training to educate the people responsible for the transition to metric, and implementation training to teach specific metric skills to specific employees.
8. Train at the right time. Training should take place just prior to when an employee will use the new knowledge on the job; earlier training is ineffective.
9. Train only as needed. Train only as necessary to meet the goal of "enabling employees to perform their jobs with the same or greater degree of efficiency using metric." Training is not a panacea, and massive training programs are wasteful. Often, training can be performed completely on-the-job.
10. Train people to "think" metric. Link metric measurements to familiar objects. Avoid converting to "inch-pound" units as much as possible. For linear measurements use dual unit tape measures.
11. Monitor the metrication program. Make sure training matches the organization's metric transition schedule. If something changes, adjust either the training or the schedule.
12. Don't hide costs. There is a cost to metric conversion, both in time and money. Plan for it in advance, and monitor costs as transition takes place.

6.2. Metric Conversion Process

Individual companies in the construction industry such as architecture, engineering, lumber, concrete, masonry, steel, plumbing, electrical, etc., should be involved in arriving at a consensus and insuring coordination. At same time, planning must begin within each company. At an appropriate point in the timetable, the company plans must be put into effect.[17-23]

6.2.1. Investigation Phase

During the Investigation Phase, predictions must be made as to the dates metric-planned projects will be on the drawing boards, the first production of metric materials, the final production of traditional materials, agreement for rationalization of sizes, and the revision of building codes. Requirements for the Investigation Phase include:

1. Investigate the implications of metric conversion for all parts of the organization, with particular emphasis on standardization and increased efficiency.
2. Identify the needs of each part of the firm during the changeover, with emphasis on metric standards and units to be used, education and training, and equipment conversion.
3. Identify the needs and modifications to internal information systems.
4. Estimate the costs of alternative approaches to metric conversion.
5. Prepare an initial schedule for the organization's metric conversion plan after considering plans of customers and suppliers.
6. Investigate opportunities for increased productivity as a result of rationalization.
7. Make recommendations to management prior to the date required.

6.2.2. Planning Phase

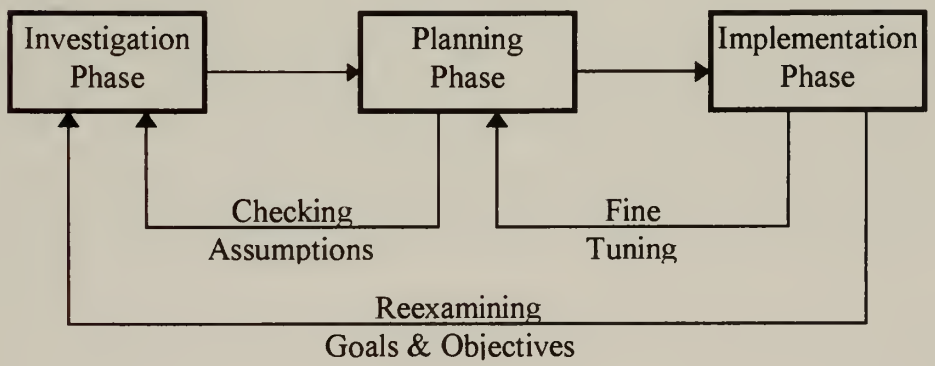
The Planning Phase will involve everyone in the industry from architects and engineers to carpenters and masons. During this phase everyone will be working hard and trying new approaches. Recommendations for the Planning Phase include:

1. Work with the trade and professional organizations as firm's business indicates. Further plans through these sources should be developed.
2. Work with local chapters of the firm's national affiliation to complete detailed local plans. At this time, may wish to consult with related trade organizations.
3. Complete plans for product changes and dates of manufacture of use in the firm's projects. Same time phase out manufacture and use of traditional sized materials.
4. Assess training requirements for all employees. Schedule training sessions. Develop training aids.
5. Check to see if any changes are required in local or state laws to facilitate the changeover. Work with local and national associations and politicians to implement these.
6. In larger firms, write or rewrite a policy manual in metric terms.
7. Investigate availability of metric materials, supplies and products. Schedule the purchase of these items.
8. Manufacturers should redesign containers, packages, labels. Expedite the provision of new sales literature and technical data sheets.
9. Determine and schedule changes in business administration and accounting procedures.
10. Announce company policy and schedule to all personnel.
11. Seek approval from management of a detailed plan incorporating who, what, when and where.

6.2.3. Implementation Phase

As part of this phase, primary focus will be on the actions planned up to this point. All plans should be put into effect and provide for modifications and rescheduling as indicated by experience. In addition to above phases, Implementation Phase will be characterized by cleaning up and finishing off uncompleted changeovers. During this phase the phasing out of traditional sizes, regulations and methods will be completed. Recommendations for this phase include:[22-23]

1. "Kick-Off" this stage with a meeting to reconfirm the company commitment. Employee motivation and support should be enhanced by reviewing the importance of the program to the future of the company and thus to the job security of each employee.
2. Designate an individual Task Leader for their activity. Leaders should carefully study the plans that may affect their activity.
3. Continuous monitoring & tracking on how closely the actions are following the plans.
4. Report specific operational areas tied closely to the Planning Phase.
5. Fine tuning & adjusting can be accomplished by broad scale evaluation of their discrepancy between what expected to actual happening.
6. Reexamine goals & objectives by identifying overlooked internal capabilities or limitations that have turned out to be particularly important.



6.3. Timetable For The Change

Metric conversion process can not be completed by the federal government alone. It will require strong support and coordination from all U.S. industry leaders. If we are to make a smooth transition of our industry, the construction industry in coordination with other industrial sectors, must develop a time schedule for orderly metric conversion. Otherwise, the U.S. construction industry could find itself facing the burdensome costs and inefficiencies of using two measurement systems for decades to come. This timetable should coincide with the three phases of the Metric Conversion Process provided earlier in this chapter.

Using the conversion times of other countries as a guide, the U.S. construction industry should be able to complete the metric transition well within a decade.[17-23] The recent experiences of the British and Canada should help us recognize that, once started, the faster the transition from old to new, the less overall cost and dislocation there will be.

7. Metric Construction Case Studies

7.1. Nine Metric Projects

In January 1994, the National Institute of Building Sciences completed a preliminary report for the Army Corps of Engineers, the General Services Administration, and the Department of Veterans Affairs on several federal metric construction projects. The report included the following projects:[23-9]

1. General Services Administration Warehouse, Denver, Colorado ($900,000)
2. Border Patrol Station, Sasabe, Arizona ($3 Million).
3. Richmond Federal Center Renovation, Richmond, Virginia ($13 Million)
4. Department Of Veterans Affairs Data Center, Philadelphia, Pennsylvania ($70 Million)
5. Federal Bureau Of Investigation Regional Office Building, Washington, D.C. ($60 Million)
6. Federal Courthouse, St. Louis, Missouri ($185 Million)
7. Federal Courthouse, Kansas City, Missouri ($90 Million)
8. Federal Courthouse, Tampa, Florida ($40 Million)
9. Census Bureau Computer Center, Bowie, Maryland ($28 Million).

7.2. Findings And Lessons Learned

The preliminary report findings and lessons learned are:[23-5]

- Design Costs. The design fees for two of the early projects were slightly higher than they would have been had the projects been designed conventionally. In both cases, small fee increases were granted because government standards had not yet been converted to metric units and the architect/engineer had to make the necessary conversions.

- Construction Costs. Seven of the nine projects came in on or below budget, following a bid pattern similar to that of non-metric projects let during the same time period. The border station project, located in a remote area, was awarded slightly above the government cost estimate. The Kansas City courthouse had a negotiated contract that was initially well over budget but for reasons having little to do with metrication. Because only total costs are considered in competitively bid jobs, it is difficult to determine if specific metric products cost more than their inch-pound counterparts. Nevertheless, the findings concerning these nine projects (and many others bid to date) continue to indicate that metrication adds little to overall project costs.

- The Metric Learning Curve. Designers and builders had to make an extra effort on their first metric job, resulting in a temporary reduction in productivity until everyone "got up to speed." Metric usage required extra time, care, and attention to detail. Rethinking familiar practices, particularly in the early stages of a project, was necessary and time had to be allowed for this. After the initial learning period, however, the advantages of the metric system became evident: it was easier and faster to use and resulted in fewer errors.

- Metric Experience. Although it was not critical to have someone with metric experience on the project team, it helped. Experienced personnel gave everyone more confidence in making the many small decisions involved in the conversion process and their guidance reduced the impact of conversion on productivity, project costs, and schedules. On one project, for instance, the contractor's superintendent had previous metric experience and was able to help subcontractors interpret construction documents and prepare shop drawings.

- Project Selection. An organization's early metric projects should be as large as possible because large projects provide time for everyone on the job to learn the metric system thoroughly (in fact, they cannot avoid learning it). Large projects also provide the volume orders required to purchase metric products without a cost premium.

Small projects may not offer these advantages. The cutoff point varies depending on the nature of the project, but the GSA Philadelphia Region indicates that even projects of a few hundred thousand dollars sometimes can be executed in metric units without difficulty. Projects under $100,000 may be feasible if they do not require the small amounts of metric materials that could carry a premium price.

- Architectural Design. Architects had little difficulty learning to design in metric units. The preparation of specifications, however, took more time and effort because the availability of metric products had to be researched and non-metric product specifications converted. As architectural firms convert their in-house specification systems and product manufacturers convert their literature, this problem will disappear.

- Structural Engineering. There were no reported problems in the area of structural design. Some firms performed calculations using inch-pounds, converted the answers to metric units, and then completed the structural details.

- Mechanical Engineering. There were no reported problems in the area of mechanical design. A number of firms used mechanical design software programs that calculated in metric units.

- Cost Estimating. A conversion error in an early cost estimate for one project was the only reported problem associated with cost estimating.

- Computer-aided Design and Drafting. Computer-aided design and drafting (CADD) programs made conversion easy because users could readily work in metric scales and units.

- Codes and Standards. Few problems were encountered in this area since most codes and standards contain metric units. In one case, a building inspector was reluctant to

review metric plans. In another, a product specification was based on tests of inch-pound assemblies, which resulted in the need for extra research on the part of the specifier.

- Job-site Training. Interestingly, tradesmen are adapting to metric usage so readily that job-site training has not been widely used. Of course, everyone on the job must be equipped with metric measuring tapes.

- Metric Tools. Metric measuring tapes were not provided to the trades on one project, causing confusion and delays. The availability of metric tools must be ensured. On one project, the contractor supplied metric measuring tapes to everyone and insisted that metric terms be used in all job-site discussions, a strategy that proved successful.

- Reverse Conversion. A mistake by a contractor in converting metric dimensions back to inch-pounds led to a significant ordering error on one project. Continuous effort is needed to discourage reverse converting.

- Shop Drawings. Shop drawing submittals have been the only metric-related problem on the job-site; a higher rate of shop drawing rejections and a significant number of mark-ups have been reported. In a few instances, subcontractors submitted metric shop drawings but used drawings with dual notations in the field. A metric orientation program for subcontractors prior to the beginning of a job can reduce such problems.

- Building Products. Some project participants were concerned that metric modular products might not be available locally or produced by enough manufacturers to promote competitive bidding. However, all product availability concerns have been resolved with no project delays or increased costs. Project designers must contact suppliers during the design stage to ensure that the products being considered are available locally. Building product data increasingly are available in metric units. Some manufacturers have always provided metric data. Others have begun to add it

to their catalogs and advertising literature. Discussions with manufacturers during the development of product specifications help ensure a competitive supply of metric components. Effective communication among designers, managers, contractors, subcontractors, and manufacturers and the identification of critical metric dimensions will reduce contractor requests for product specification changes.

- Systems Furniture. Office furniture systems are manufactured in inch-pound modules but will work in metric layouts if care is taken in choosing the appropriate module sizes. Problems can be minimized by avoiding shortcuts and checking calculations.

- Utilities. Local government and utility records are not maintained in metric units and local authorities may require submittals in inch-pound units. On one project, the utility company resisted reviewing metric drawings.

- Clients and Tenants. Clients and tenants often have difficulty understanding space requirements when metric units are used. Allow for the extra time needed to assist them in this regard.

- Federal Commitment. Many study participants emphasized the need for the federal government to show an unequivocal commitment to metrication. Only a strong federal commitment will provide the necessary incentive for the construction industry to smoothly convert to the metric system.

7.3. Positive Approaches To Metric

A positive approach to metric construction seems to work best. It involves:[23-7]

- Making a firm commitment to metrication.
- Choosing projects of significant size.
- Using available CADD technology.

- Conveying a positive message about metrication to all project personnel and constantly reinforcing it.
- Providing metric orientation for construction trades.
- Accepting the increase in effort needed to ascend the metric learning curve.
- Devoting extra attention to details and checking calculations.
- Requiring metric-only usage in the provisions of all design and construction contracts.

8. Conclusion

As provider of the nation's highways, bridges, dams, water and sewer systems, parks, prisons, military bases, space centers, laboratories, embassies, courthouses, schools, and numerous other public facilities, the United States Government is a major player in the construction industry. Federal appropriations for construction, including grants to state and local governments, total about $50 billion annually.

Federal construction projects are providing the catalyst for the metrication of the nation's construction industry. Almost all federal construction programs are now converted to the metric system and most agencies are designing and constructing projects in metric units. All major metric projects to date have been awarded under budget, verifying that it is good project management and the local bidding climate, not the use of the metric system, that determines whether or not projects meet their cost estimates.

In the past three years, billions of dollars in federally funded metric projects have been placed under construction and as noted earlier in this report:

- Conversion has proven to be much less difficult than anticipated.
- There has been no appreciable increase in design or construction costs.
- Architects and engineers like working in metric units.
- Tradesmen adapt readily to metric measures on the job site.
- Construction and product problems have been minimal.

The influence of government's buying power and the rapid globalization of the construction industry will likely force conversion of all nonresidential construction to the metric system within a matter of time. Residential construction, although not as affected by the governmental work or foreign market, (but still are closely related with the rest of the construction industry) will follow in adopting the metric system.

When it does, metrication will bring more than efficiency and better quality control to construction. It will benefit every American by helping our nation compete more effectively in the global marketplace. Similarly, the sooner the metric changeover is completed, the less it will cost and the sooner everybody will start accumulating the savings brought on by a simpler system of measurements.

9. Recommendations

Each Federal construction agencies have developed specific timetables and milestones for changing into the metric system. However, not all activities within those agencies have or been able to meet all of the goals & objectives.

Currently the Federal government is in the Implementation Phase of the Metric Conversion Process. Similarly, as specified earlier in this report (6.3.3.), following recommendations are suggested for the Federal government's metrication process:

1. Federal employee motivation and support should be enhanced by reviewing the importance as well as the benefits of the program.
2. Designate an activity leader for each organization. Leaders should carefully study the plans that may specifically affect their activity.
3. Continuous monitoring & tracking on how closely the actions are to the specific timetables and milestones developed for changing to the metric system.
4. Fine tuning & adjusting by broad scale evaluation of their discrepancy between what expected to actual happening.
5. Reexamine goals & objectives by identifying overlooked internal and external capabilities or limitations that have turned out to be particularly important.

The progress within each agencies and activities should be closely monitored and evaluated in order to maintain its full momentum of the metrication process. The public must be continuously informed of the nation's metrication progress as well as being ensured of government's commitment to the metric system. Without it, doubts about the metric transition will increase and the public will lose interest.

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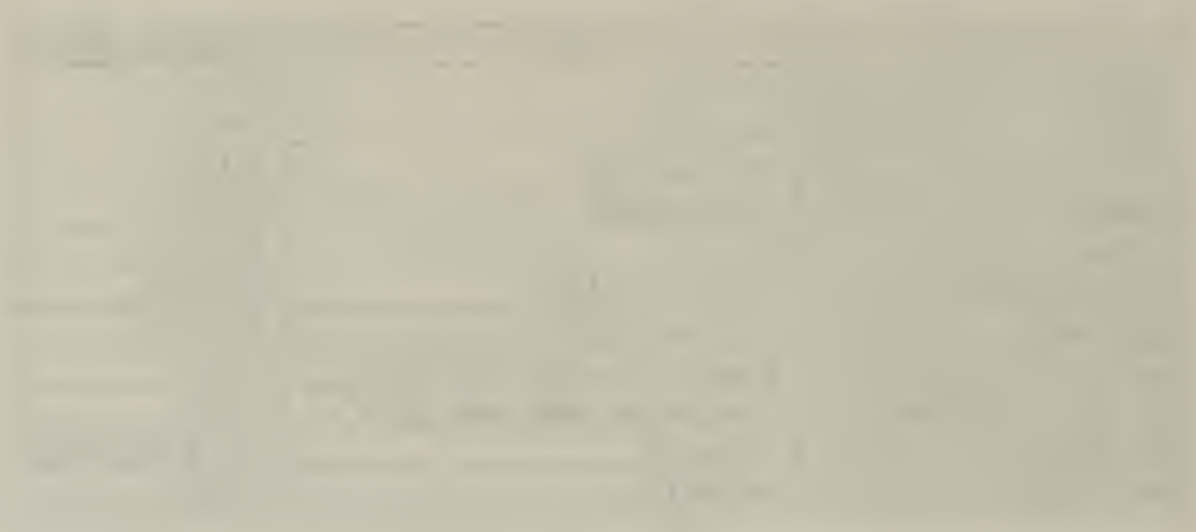
Appendix A - Common Metric Conversion Factors

To Covert	To	Multiply By
inches	meters (m)	0.0254
feet	meters (m)	0.3048
pounds	kilograms (kg)	0.4535924
fluid ounces	milliliters (mL)	29.57353
gallons	liters (L)	3.7854118
pounds per inch (psi)	megapascals (MPa)	0.00689476
cubic yards	cubic meters (m^3)	0.7645549
pounds per cubic yard	kilograms per cubic meter (kg/m^3)	0.5933
pounds per cubic feet	kilograms per cubic meter (kg/m^3)	16.01846
Fahrenheit (F)	Celsius (C)	5/9 x (& deg; F-32)
pound force	newton (N)	4.448222



Appendix B - Common Metric Units Of Construction Trades

Trade	Quantity	Unit	Symbol
Surveying	length	kilometer	km, m
	area	square kilometer hectare (10,000 m^2) square meter	km^2 ha m^2
	plane angle	degree (non-metric) minute (non-metric) second (non-metric	° ‘ “
Excavating	length	meter, millimeter	m, mm
	volume	cubic meter	m^3
Trucking	distance	kilometer	km
	volume	cubic meter	m^3
	mass (weight)	metric ton (1000 kg)	t
Paving	length	meter, millimeter	m, mm
	area	square meter	m^2
Concrete	length	meter, millimeter	m, mm
	area	square meter	m^2
	volume	cubic meter	m^3
	temperature	degree Celsius	°C
	water capacity	liter (1000 cm^3)	L
	mass (weight)	kilogram, gram	kg, g
	cross-sectional area	square millimeter	mm^2
Masonry	length	meter, millimeter	m, mm
	area	square meter	m^2
	mortar volume	cubic meter	m^3
Steel	length	meter, millimeter	m, mm
	mass (weight)	metric ton (1000 kg) kilogram, gram	t kg, g
Carpentry	length	meter, millimeter	m, mm
Plastering	length	meter, millimeter	m, mm
	area	square meter	m^2
	water capacity	liter (1000 cm^3)	L
Glazing	length	meter, millimeter	m, mm
	area	square meter	m^2
Painting	length	meter, millimeter	m, mm
	area	square meter	m^2
	water capacity	liter (1000 cm^3) milliliter (cm^3)	L mL
Roofing	length	meter, millimeter	m, mm

	area	square meter	m^2
	slope	millimeter/meter	mm/m
Plumbing	length	meter, millimeter	m, mm
	mass (weight)	kilogram, gram	kg, g
	capacity	liter (1000 cm^3)	L
	pressure	kilopascal	kPa
Drainage	length	meter, millimeter	m, mm
	area	hectare (10000 m^2) square meter	ha m^2
	volume	cubic meter	m^3
	slope	millimeter/meter	mm/m
HVAC	length	meter, millimeter	m, mm
	volume	cubic meter	m^3
	capacity	liter (1000 cm^3)	L
	airflow	meter/second	m/s
	volume flow	cubic meter/second liter/second	m^3/s L/s
	temperature	degree Celsius	°C
	force	newton, kilonewton	N, kN
	pressure	kilopascal	kPa
	energy, work	kilojoule, megajoule	kJ, MJ
	rate of heat flow	watt, kilowatt	W, kW
Electrical	length	meter, millimeter	m, mm
	frequency	hertz	Hz
	power	watt, kilowatt	W, kW
	energy	megajoule kilowatt hour	MJ kWh
	electric current	ampere	A
	electric potential	volt, kilovolt	V, kV
	resistance	ohm	Ω

Appendix C - U.S. Codes, Standards, Professional & Trade Organizations

The Construction Metrication Council recently compiled a broad sample of U.S. codes, standards, professional, and trade organizations to report on their current metrication activities.

- American Association of State Highway Transportation Officials (AASHTO). In June, AASHTO published the Guide to Metric Conversion for use by states in meeting the Federal Highway Administration's (FHWA) mandate that all federally aided highway projects after October 1996 be built in metric. An AASHTO metric task force, with funds provided by the federal Transportation Research Board, is establishing a metric information clearinghouse and an electronic bulletin board to help the states set uniform metric procedures and standards. Recently, AASHTO requested additional funds from the Transportation Research Board for converting its technical standards and computer software to metric.

- Air-Conditioning and Refrigeration Institute (ARI). ARI's metric policy states that each ARI section is to adopt an international standard within one year of publication or explain why such a standard cannot be adopted. To assist in this process, ARI has issued a new guidance document, Use of SI Units in ARI Standards.

- American Consulting Engineers Council (ACEC). At ACEC's Fall Conference, a new metric policy was proposed that includes the development of an active program for encouraging members to prepare for metrication and empowering staff to support member metrication needs. The conference included a special session on metrication. ACEC has printed numerous articles about metrication in its publications, sells the NIBS Metric Guide to Federal Construction, and promotes the Metric in Construction newsletter to its members.

- American Concrete Institute (ACI). ACI has supported the voluntary conversion to metric since 1987. Two of its principal publications, Building Code Requirements for Reinforced Concrete and Building Code Requirements for Plain Concrete, are available in metric editions. ACI is considering a timetable for converting its remaining documents to hard metric as early as 1998.

- American Concrete Pipe Association (ACPA). The concrete pipe industry has been involved in metrication since the early 1970s. To date, 22 American Society for Testing and Materials (ASTM) standards on concrete pipe have been issued in metric units. ACPA is revising its design manuals, handbooks, software, and marketing materials to include metric by 1996. Meanwhile, it is encouraging concrete pipe manufacturers to develop new design drawings, revise promotional materials, modify purchasing, update records, and train plant personnel to mark products in metric units.

- American Congress on Surveying and Mapping (ACSM). ACSM first published the Metric Practice Guide for Surveying and Mapping in 1978. To date, about 20 states

have adopted legislation to permit the use of the metric system as the basis for their state plane coordinate systems. The recent FHWA mandate to produce surveys and maps for highway design and construction in the metric system has heightened interest in metric. The September-October 1993 ACSM Bulletin carried two articles about metric conversion.

- American Forest and Paper Association (AFPA). AFPA is about to issue a new edition of the Metric Planning Package for the Wood Products Industry. First published in the 1970s, it includes industry recommendations for metric conversion. The 1996 edition of the National Design Specification for Wood Construction will include metric units as will the LRFD for Engineered Wood Construction. Metric units will be added to other AFPA publications as appropriate.

- American Institute of Architects (AIA). AIA's policy supporting metric goes back to the 1940s. It is now printing an AIA Pocket Metric Guide to promote metrication in the architectural field. A metric version of MASTERSPEC is virtually complete and will be available by the end of the year. Metric units are being added incrementally to Architectural Graphic Standards and a complete metric edition is being considered for the tenth edition, which could be published as early as 1996.

- American Institute for Hollow Structural Sections (AIHSS). AIHSS recently completed two metric guides for use by its members: Summary of Presentation Factors and Procedures for Determining Properties of Square and Rectangular HHS/Structural Steel Tubing from U.S. Customary Units to Metric Units and Recommendations for Soft Conversion of Dimensions of Square, Rectangular, and Round HSS/Structural Steel Tubing from U.S. Customary Units to Metric Units. Both documents apply to structural steel components specified in ASTM A500.

- American Institute of Steel Construction (AISC). AISC recently published the Metric Properties of Structural Shapes with Dimensions According to ASTM A6M, first issued last year in draft form. A complete metric edition of the LRFD Manual of Steel Construction will be available in late 1994. AISC is working with the Industrial Fasteners Institute to develop a policy on the metrication of structural steel bolts.

- American Iron and Steel Institute (AISI). AISI members who ship mill products to the construction market support the activities of the Construction Metrication Council. Basic steel mill products are available today in metric sizes and voluntary consensus standards for these products are available through ASTM and other organizations. AISI is working closely with allied trade organizations to help implement metric and is developing metric engineering aids for steel bridge design as well as adding metric units to its design manual for cold-formed steel structures.

- American Public Works Association (APWA). APWA has adopted a policy in support of metric conversion that reflects a growing interest in metric among its members. A session on metrication was held at the Public Works Congress and Exposition in San

Francisco last spring and was well received. APWA has included two major articles on metric in its monthly magazine and presently is drafting A Public Works Guide to Metrication that provides a background on the metric system, reasons for converting, metric conventions, and guidelines for a smooth transition.

- American National Standards Institute (ANSI). In October, ANSI adopted a policy stating that units of the modernized metric system (SI) are the preferred units of measurement in American National Standards. To facilitate implementation of this policy, ANSI has formed a Task Group on Metrication to encourage and assist ANSI member organizations in converting their standards. The task group first met in September and is open to interested parties.

- American Society of Civil Engineers (ASCE). ASCE has supported use of the metric system since 1876. Its most recent metric policy, adopted in 1991, states that ASCE will actively support the metrication of civil engineering practice and research, implement the use of metric units in all ASCE publications, and encourage civil engineering schools to stress the use of metric in instruction. Since January 1993, ASCE has mandated that metric be included as the primary unit in all new and revised standards with no other units being required. ASCE regularly includes metric articles in its periodicals, provides metric literature at its conferences, and has a Committee on Metrication with over 90 members.

- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). ASHRAE's four handbooks are available in both inch-pound and metric editions. Its 80-plus standards contain metric units as do the proceedings of its semiannual meetings and conferences. Goal 15 of ASHRAE's strategic plan states that ASHRAE will implement a policy on and promote utilization of metric units by the HVAC&R and allied industries. Objective 15.1 is to develop and implement a plan that will promote and assist the HVAC&R and allied industries in implementing the use of metric units by the year 2000 and Objective 15.2 is to develop and implement a plan to use only metric units in ASHRAE publications by the year 2000.

- American Society of Mechanical Engineers (ASME). ASME supports a national program of metric conversion. All ASME standards contain metric units except the Boiler and Pressure Vessel Code, which is being converted now. ASME has set a target date of 1998 for the publication of its codes and standards only in metric. ASME provides staff support to the Mechanical Task Group of the Construction Metrication Council.

- American Society for Testing and Materials (ASTM). ASTM requires the use of metric in all its standards. Currently, 38 technical committees are developing standards in hard metric and another 7 are in the process of converting to hard metric. In total, approximately 1600 ASTM standards use only metric units, 3500 use metric as the primary unit, and the remaining 3000 use metric as the secondary unit. Recently, ASTM and the Institute of Electrical and Electronics Engineers (IEEE) have begun

negotiations to merge their two metric standards, ASTM E380-93, Standard Practice for the Use of International Units, and ANSI/IEEE 268, American National Standard Metric Practice.

- American Water Works Association (AWWA). AWWA has undertaken a program to convert its publications and other documents to metric by January 1997. Metric units have been added to many of AWWA's 120 water supply product and procedural standards, whose increasing usage on an international basis makes metrication a timely issue.

- Architectural Precast Association (APA). APA supports the Precast/Prestressed Concrete Institute's recommendations on metric conversion. APA members, who make nonstructural architectural precast cladding, view metrication favorably and generally foresee no problems in producing in metric.

- Associated Builders and Contractors (ABC). ABC is using its national publications and training programs to inform and educate members about metric. During the past year, all ABC's publications--Monthly Regulatory Update, ABC Today, and Heavy/Highway Report--have carried articles on metric. ABC's craft training manuals for electricians, millwrights, pipe-fitters, welders, carpenters, plumbers, sheet metal workers, metal building assemblers, and instrumentation control mechanics incorporate metric in their core curricula.

- Associated General Contractors of America (AGC). AGC formed a metric task force in 1992. Many AGC members are large contractors who have experience in metric and foresee no problems in using it. AGC regularly provides copies of the Metric in Construction newsletter to two of its large committees and several AGC chapters. Two sessions on metric were held at AGC's annual conference in Las Vegas last spring.

- Brick Institute of America (BIA). BIA has adopted a metric policy stating that it:
    1. supports conversion to metric units of measure as an inevitable action
    2. will continue to provide information in both metric and inch-pound units, as it has since 1978
    3. encourages all brick manufacturers and distributors to publish their product literature and other design data in equivalent metric versions or with both inch-pound and metric units
    4. will work with brick manufacturers to promote the use and manufacture of modular metric sizes through its technical, marketing, and informational publications
    5. will continue to work with the federal government and within the codes and standards organizations to provide masonry codes, standards, and specification in correct metric units

6. encourages the training of bricklayers in vocational programs in the use of the metric system as it relates to brick masonry. In addition, BIA anticipates the publication of a new Technical Notes on modular metric brick.

- Concrete Reinforcing Steel Institute (CRSI). CRSI has undertaken several metric initiatives during the past year. It presented 20 seminars in key cities across the United States on the metrication of reinforced concrete design and construction. Four more seminars are planned for the first half of 1994. CRSI has initiated the development of several metric design and detailing aids including printed metric bar cards and a computer program, DEVLAPM, for determining development and lap splice lengths for metric reinforcing bars. Metric versions of a wall bar chart will be completed by the end of this year and a metric version of the CRSI Manual of Standard Practice is being prepared. CRSI will begin converting its other technical publications and design aids in 1994. Lately, CRSI staff has been responding to a significant number of inquiries about metric.

- Construction Specifications Institute (CSI). In February 1992, CSI instituted a policy of adding metric units to its new and revised documents and publications, although SPECTEXT, the Master guide specification owned by the Construction Science Research Foundation (CSRF), has always contained metric units. Last year, metric units were added to CSI's Manual of Practice and they are now being added to CSI's SpecGUIDEs. CSI is encouraging manufacturers to convert their SPEC-DATA and MANU-SPEC product data sheets to metric. CSI's magazine, Construction Specifier, began using metric as the primary unit in June 1992 and features a monthly column on metrication. CSI's monthly newsletter, NEWSDigest, regularly features metric updates.

- Council of American Building Officials (CABO). CABO is made up of the three model code organizations--BOCA, SBCCI, and ICBO. The BOCA National Codes have included metric units since 1975. SBCCI added metric units to its Standard Building Code in 1991 and will add them to the balance of its codes 1994. ICBO will add metric units to its Uniform Codes in 1994. Metric will be added to the CABO One- and Two-Family Dwelling Code in 1995. CABO is secretariat to the ANSI A117.1 accessibility code, which has contained metric units since its inception. All three model code organizations support the Construction Metrication Council and have published articles about metrication in their magazines.

- Gypsum Association. The Gypsum Association has no policy on metrication but notes that many of its member manufacturers can provide hard metric gypsum products now.

- Hardwood Plywood and Veneer Association (HPVA). Last year, HPVA revised its Interim Voluntary Standard for Hardwood and Decorative Plywood to include metric units. Now it is adding metric to its other two standards, ANSI/HPMA LHF, American National Standard for Laminated Hardwood Flooring, and DFV-1 Voluntary Standard for Sliced Decorative Wood Face Veneer.

- Institute of the Ironworking Industry (III). III reports that the International Association of Bridge Structural and Ornamental Iron Workers recently published a 100-page apprentice and journeyman student guide titled Metrics for Ironworkers.

- Instrument Society of America (ISA). ISA produces instrument and control systems standards for the HVAC and industrial process industries in the United States and abroad. ISA supports federal metrication efforts and believes that the country's adoption of metric will increase its global competitiveness. All new and recently revised ISA standards express measurements in metric units.

- International Association of Plumbing and Mechanical Officials (IAPMO). IAPMO is incorporating metric units in its standards and other publications and is adding metric to the 1994 edition of its plumbing code, published by ICBO as the Uniform Plumbing Code.

- International Concrete Repair Institute (ICRI). ICRI regularly informs its members about the progress of construction metrication through its Concrete Repair Bulletin and uses metric units in its publications.

- Kitchen Cabinet Manufacturers Association (KCMA). KCMA supports metric conversion and encourages its members to add metric to their product literature. Its cabinet standard, ANSI/KCMA A161.1, Recommended Performance & Construction Standards for Kitchen and Vanity Cabinets, includes metric units.

- Mechanical Contractors Association of America (MCAA). MCAA publishes information about metric conversion in its newsletter and participates in the Mechanical Task Group of the Construction Metrication Council.

- National Association of Architectural Metal Manufacturers (NAAMM). NAAMM is adding metric units to its standards and does not foresee any significant problems in the conversion of architectural metal products to metric.

- National Fire Protection Association (NFPA). NFPA codes and standards have included metric units since the 1970s. Converting measurements to hard metric will require the submittal of proposals through the standards-making process.

- National Glass Association (NGA). The glass industry is international and most NGA members work in metric now. Since the making of float glass is computer controlled, it can be produced in any size and thickness. NGA's Glass Magazine published one of the first construction industry articles on metric in February 1992.

- National Particleboard Association (NPA). NPA recently issued a revised version of its standard, ANSI A208.1-1993, Particleboard, in hard metric. During the conversion process, the number of particleboard grades was reduced from 19 to 12.

- National Roofing Contractors Association (NRCA). NRCA has approved a policy to support metric conversion in the roofing industry and to implement the use of metric units in all NRCA publications, manuals, programs, research, and instructional materials. NRCA's metric committee has made the following recommendations: get news of federal metrication activities into the hands of members, emphasize that metric conversion will not be as difficult as it may seem, and implement metric educational programs. The committee also is exploring the kinds of metric tools and devices it should recommend to its members.

- National Society of Professional Engineers (NSPE). NSPE has supported metric conversion since the 1970s. After passage of the 1988 amendments to the Metric Usage Act, NSPE extended its support to federal metrication efforts and instituted a program to increase metric awareness among its members. NSPE routinely answers queries about metric received through its state chapter computer network.

- National Stone Association (NSA). NSA has an active information program to help its members prepare for metric conversion. After discussing metrication in several forums, NSA has concluded that there will be no significant impact on the stone industry. Stone products are typically specified by gradations determined through sieve analysis. Testing sieves are in metric sizes now with nominal inch-pound names provided for current use; therefore, the gradation of products will not change, just the units in the specification. The industry's equipment suppliers are for the most part international and their equipment is predominantly metric. The only remaining task is the conversion of computer software used by quarry operators for weighing and invoicing trucks so their weights can be recorded in kilograms and metric tons.

- North American Insulation Manufacturers Association (NAIMA). NAIMA regularly sends its member companies information on federal metrication activities. Many NAIMA members have international operations and make metric products now.

- Portland Cement Association (PCA). PCA's metric policy states that all publications, videotapes, slide sets, and computer programs will be developed to include metric units. Metric has been added to most of PCA's recently updated publications and its concrete design computer programs have metric capability now.

- Precast/Prestressed Concrete Institute (PCI). PCI supports the FHWA's metric conversion policy as it applies to precast/prestressed concrete bridge products. PCI advocates an initial soft conversion by rounding all dimensions to the nearest 5 mm, followed over time by a hard conversion. All new PCI publications include metric units and a metric edition of PCI's Design Handbook is being considered for publication in 1996.

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